

Marine Mammals

Andrew Trites and Kathy Heise

Thirteen species of marine mammals feed in the Gulf of Alaska gyre during summer and winter. These were grouped into five categories: pinnipeds, toothed whales, baleen whales, beaked whales and killer whales (resident and transient). Estimates of mean body weight (wet, i.e., live weight) for males and females of each species were obtained from Trites and Pauly (in prep.). Population estimates were obtained from published sources or educated guesses based on the best available information, such as Northridge's (1991) global population estimates. Unless otherwise stated, individual ration (R, in % of body weight day⁻¹) was estimated for each species and sex using:

$$R = 0.1 \cdot W_{i,s}^{0.8}$$

where $W_{i,s}$ is the mean body weight in kg of species (i) and sex (s), 0.8 is from Eq. 23 in Innes et al. (1987), and 0.1 is a downward adjusted value (from 0.123 in Innes et al.), which account for the difference between ingestion for growth and ingestion for maintenance.

Estimates of daily ration ranged from 1.7% of body weight in a 6,100 kg minke whale (107 kg day⁻¹), to 5% of body weight per day in a 32 kg harbour porpoise (1.6 kg day⁻¹), and are compatible with present knowledge of the biology of large and small marine mammals (Bonner 1989). Dietary composition was determined from stomach and fecal remains reported in published sources for each species (e.g., Perez 1990). Dietary composition for pinnipeds, toothed whales, baleen whales and beaked whales was set equal to the mean diet of the species within the grouping, weighted by the relative population abundance and daily ration estimates for each species.

Detailed summer and winter population and prey composition data for all 13 marine mammal species are summarized in Appendix 1, Tables A - C. Additional information concerning the assumptions and estimates used for each species of marine mammal in the Alaskan gyre is given below.

Pinnipeds

Northern fur seals and northern elephant seals are found in the Alaska gyre in both summer and winter. A third species, the Steller sea lion, feeds in the gyre during winter. The maximum rate of population growth for northern fur seals and other pinnipeds is believed to be about 12% (Small and DeMaster 1995). The P/B ratio was therefore set at 6%, half of the maximum.

Northern fur seals (*Callorhinus ursinus*) from the Pribilof Islands numbered 1,019,192 in 1994 (Small and DeMaster 1995). Their annual migration extends from the Bering Sea to the coastal waters of California. Much of the population migrates through the Western Gulf of Alaska from April to July

(Bigg 1990). Between 10% and 25% of the population feed in the Alaska Gyre on their return to the breeding islands in the Bering Sea (10% in April, 25% May, 23% June, and 20% July, as calculated from the number of fur seals sighted in all areas of the north Pacific during pelagic surveys shown in Figure 8 of Bigg (1990). This represents 13% of the total population over the 6 summer months or 130,000 fur seals per month. 5,000 fur seals were assumed to be present from October to March, given that few, if any, appear to be in the gyre during winter (Bigg 1990). The ratio of males to females was assumed to be 1:4 in both seasons. Mean body weight of males (30.2 kg) and females (25.3 kg) were taken from Trites and Pauly (in prep.).

Dietary information was based on stomach contents from fur seals shot at sea from 1956 to 1972 (Perez and Bigg 1981, 1986). The Gulf of Alaska gyre corresponds to Area 16 of the fur seal pelagic survey (Table 19 of Perez and Bigg 1981) where, in the summer, the animals eat predominately squid (78%), salmon (11%), rockfish (8%), and pollock (3%). While no animals have been collected in the gyre during the winter, it is reasonable to assume that a few must feed here. Without dietary information it was assumed that the animals had consumed a generic diet, taken from Pauly et al. (1995).

Northern elephant seals (*Mirounga angustirostris*) make biannual migrations from the breeding beaches in California to deep waters of the Gulf of Alaska (DeLong et al 1992; LeBoeuf 1994; Stewart and DeLong 1994, 1995). Males go further north than females and may feed in the Alaska Gyre for 30-50 days of each trip, before returning south. It was assumed that 40% of the male population spent up to one month in the gyre in the summer and another month feeding in the area in winter. Given the current population estimate of 127,000 elephant seals (Stewart et al. 1994) and an assumed sex ratio of 50%, approximately 4,000 males should be present in each of the 6 months of summer and winter.

In the absence of dietary information for elephant seals feeding in the Gulf, it was assumed that they ate 40% small squid, 20% dogfish, 10% rockfish, 10% sablefish, 10% hake and 10% miscellaneous demersal fish, based on dietary composition estimates from elephant seals sampled in California (Antonellis et al. 1984). Mean body weight was taken from Trites and Pauly (in prep.).

Steller sea lions (*Eumetopias jubatus*) breed on offshore rocks and islands from California to northern Japan. They generally feed within 20 km of shore during summer, but venture several hundred km during winter (Merrick 1995). The western Gulf of Alaska population numbered approximately 15,000 in 1994 (Trites and Larkin 1996) and has declined by over 65% since 1980. Winter diet is not precisely known, but was assumed to consist of 15% squid, 20% small pelagic fishes (capelin, mackerel, herring), and 65% large pelagic fishes (mostly pollock), based on dietary information compiled by Merrick (1994). Mean body weight was taken from Trites and Pauly (in prep.).

Baleen Whales

Three species of baleen whales are found in the Alaska gyre during summer months: blue, fin and sei whales. Minke and humpback whales are primarily coastal species (Leatherwood et al. 1982; Jefferson et al. 1993) and were not considered to occur in significant numbers in the gyre. All of the baleen whales show seasonal movements into southern latitudes in winter months (Leatherwood et al. 1982), and are

not present in the gyre in winter.

The maximum rate of population increase assumed for baleen whales is 4% (Reilly and Barlow 1986) and production was estimated to be 2% (half of r_{max}). Much of the information on distributions and diet was obtained through historical whaling accounts from the coast of Japan, the Gulf of Alaska and the coast of British Columbia (see, e.g., Scammon 1874; Townsend 1935; Nemoto 1959; Nichol and Heise 1992).

Blue whales (*Balaenoptera musculus*) wintering off the coast of California and Mexico number 1,700 (Small and DeMaster 1995), but no estimates are available for populations summering further north. The Gulf of Alaska is the northern limit of the range of blue whales (Jefferson et al. 1993). An evenly distributed summer population size of 1,700 animals (range 1,000-3,000) was assumed.

Blue whales consume 40 g of food per kg of body weight per day during the summer feeding season and increase their body mass by 50% (Lockyer 1981b). Dietary information obtained from historical whaling accounts from Japan and British Columbia show blue whales to feed primarily on euphausiids (95%) and occasionally on copepods (5%) (Nemoto 1959; Nichol and Heise 1992).

Fin whales (*Balaenoptera physalus*), like blue whales, extend their feeding range into the Gulf of Alaska during the summer months. Fin whales increase their weight by an estimated 30% over the summer months, with a daily ration of about 40g per kg body weight (Lockyer 1981b). Dietary information obtained from historical whaling accounts indicates that fin whales feed on euphausiids (75%), copepods (20%), and fish (5%) (Nemoto 1959, Nemoto and Kawamura 1977, Nichol and Heise 1992).

Fin whales, once the most abundant baleen whale in the world's oceans (Evans 1987), were commonly taken by whalers, but are presently listed as endangered (Small and DeMaster 1995). Current population estimates range from 17,000 to 20,000 in the North Pacific (Evans 1987; Gambell 1985a).

Sei whales (*Balaenoptera borealis*) are primarily an offshore species with an estimated population of 14,000 animals in the North Pacific (Gambell 1985b). Like other baleen whales, they move into cooler waters in summer to feed and move into lower latitudes in winter to breed. It was assumed that they feed at approximately the same summer feeding rate as do the other baleen whales (4% of body weight \times day⁻¹, Lockyer 1981b). Based on historical whaling data, sei whales feed primarily on copepods (80%), followed by small squid (5%) euphausiids (10%) and small pelagic fish (5%) (Nemoto 1959; Nichol and Heise 1992).

Toothed Whales

Dall's porpoises, killer whales and sperm whales are found in the Alaskan gyre in summer. The maximum rate of population increase for all toothed whales is believed to be 4% (Reilly and Barlow 1986) and annual production was estimated to be 2% of biomass (half of r_{max}).

Sperm whales (*Physeter macrocephalus*) are found in the gyre in summer only, and all individuals are mature males. Much of the information available on the distribution and diet of sperm whales was obtained through historical whaling accounts from the coast of Japan, the Gulf of Alaska and the coast of British Columbia (e.g. Townsend 1935, Nichol and Heise 1992). According to Townsend (1935), sperm whales north of 49° N were "stragglers" from the breeding groups of sperm whales found further south. It was assumed that 2,000 sperm whales were present in the Pacific north of 45° N in summer. The average weight of mature sperm whales in the Antarctic was 27.4 t, and they consumed approximately 3% of their biomass per day (Lockyer 1981a). These parameters were assumed to apply to the mature males found in the gyre in summer.

Diet information from the Gulf of Alaska was not available, and thus, historical records of the stomach contents of 501 whales harvested off the west coast of Vancouver Island (Nichol and Heise 1992) were used here. They indicate that sperm whales feed primarily on large squid (80%), but also consume small squid (5%). Fish were also consumed, notably the ragfish *Icosteus aenigmaticus* (15%).

Resident killer whales (*Orcinus orca*) in British Columbia and in Prince William Sound, Alaska eat fish (Bigg et al. 1990; Heise et al. 1992; Ford et al. 1994). Approximately 238 resident whales live in the Gulf of Alaska and the Bering Sea. Diet information from stomach contents is not available for this area, but there are many reports of killer whales raiding commercial longline gear in the Gulf of Alaska and in the Bering Sea. Based on this, and on studies of killer whales from other areas, resident killer whales in the Gulf of Alaska gyre are assumed to eat primarily salmon (80%), as well as large (10%) and small pelagics (10%). The winter diet is assumed to contain less salmon (60%), and an increased number of large and small pelagics (20% each). Adjusting for the age structure of the killer whale population and the caloric value of prey, Barrett-Lennard et al. (1995) estimated that male and female killer whales consume 84.6 kg and 84.1 kg respectively of food per day, which is slightly higher than would be predicted from the empirical equation of Innes et al. (1987).

Olesiuk et al. (1990a) estimated a production of 2.92 % year⁻¹ for resident killer whales in British Columbia, while Small and DeMaster (1995) used $r_{\max} = 4\%$, a value that is considered conservative for most cetaceans (Reilly and Barlow 1986). Thus, we assume a P/B ratio of 2% for resident killer whales. Barrett-Lennard et al. (1995), based on data in Bigg et al. (1990), estimated the sex ratio of female to males to be 0.64:0.36. Mean body weight estimates are 2,587 kg for males and 1,973 kg for females (Trites and Pauly, in prep.).

Approximately half of the 88 transient (mammal-eating) killer whales that utilize the waters of western Alaska and the Bering Sea (Barrett-Lennard et al. 1995) are assumed to occur in the Gulf of Alaska. While no diet information is available from stomach contents of whales in this area, it is reasonable to assume that it is similar to transients from other areas. Based on Barrett-Lennard et al. (1995), summer diet was assumed to comprise 50% toothed whales (predominantly Dall's porpoises), 40% baleen whales and 10% pinnipeds. In winter, it was assumed that transients spent more time foraging in nearshore areas, yielding an estimated population of only 22 animals, and a diet composition of 60% toothed whales and 40% pinnipeds. The sex ratio for resident and transient killer whales was assumed to be the

same (0.64:0.36 female : male). Marine mammal prey has higher caloric value than that of fish (Perez 1990), and Barrett-Lennard et al. (1995) estimate that male and female transients consume 73 kg of prey per day.

Dall's porpoises (*Phocoenoides dalli*) are widely distributed throughout the north Pacific. Hobbs and Lerczak (1993, in Small and De Master 1995), estimated an abundance of 106,000 animals for the Gulf of Alaska. Applying a correction factor for vessel attraction (0.2, based on Turnock and Quinn 1991) gives a population abundance estimate of 21,200 (range 15,000-30,000) for the Gulf of Alaska. This estimate was used for both summer and winter models because Dall's porpoises do not appear to show strong seasonal movements (Green et al. 1992). Mean body weight estimates for males and females were 63.1 kg. and 61.4 kg, respectively (Trites and Pauly, in prep.).

The food consumption of Dall's porpoises was estimated from the equation presented above, adapted from Innes et al. (1987). The diet of Dall's porpoises from the Gulf of Alaska is not known, but Klinowska (1991) lists Pacific mackerel, sardines, saury, and squid as occurring in the diet of animals taken in the western north Pacific. The diet composition retained here is based on the stomach contents of 28 animals taken off the coast of Japan, analyzed by Wilke et al. (1953), and consisting of mesopelagics (70%), small squid (20%) and small pelagics (10%).

Beaked Whales

The maximum rate of population increase for all toothed whales is believed to be 4% (Reilly and Barlow 1986) and the production for beaked whales was set at half this value.

Baird's beaked whales (*Berardius bairdii*) are the largest of the beaked whales and may attain lengths of up to 14 m, and ages of up to 84 years (Rice 1986; Klinowska 1991). Barlow et al. (1995) estimate a total of 19 Baird's beaked whales off the coasts of California, Oregon and Washington. As the species is primarily pelagic, an evenly distributed population of 10,000 was assumed across their range (from Jefferson et al. 1993). However, most animals in the north Pacific move south in winter (Tomilin 1957). The sex ratio of adult Baird's beaked whales appears to be strongly biased towards males; for example, only 3 of 24 whales caught off Coal Harbour between 1948 and 1967 were females (Rice 1986). A male to female sex ratio of 3:2 was assumed.

Rice (1986) found primarily medium-sized squid in the stomachs of animals harvested by California whalers. Klinowska (1991) cites benthic fish and cephalopods in the stomachs of animals harvested in the western Pacific. Tomilin (1957) reports a predominance of squid in the diet, with rockfish, skate and sardines occurring less frequently in animals harvested by Soviet whalers. A diet composition of 35% large squid, 30% small squid, 25% large pelagics and 10% small pelagics was assumed.

Stejneger's beaked whales (*Mesoplodon stejnegeri*) inhabit cold temperate and subarctic waters, rarely ranging below 45° N in the eastern north Pacific (Jefferson et al. 1993). They are one of the more common species found stranded in Alaska (Zimmerman 1991), but are rarely seen at sea. It was assumed that Stejneger's beaked whales are present year round in the Gulf of Alaska gyre because there is no

seasonality to the strandings. Given no reliable population estimates are available for this species, density was based on an estimated population size of 1,000 averaged across the entire area of their distribution, which agrees with the order of magnitude estimate of Northridge (1991). Diet is primarily squid if one can trust the two stomach contents reported in Klinowska (1991), and the information in Tomilin (1957).

Cuvier's beaked whales (*Ziphius cavirostris*) are perhaps the most abundant of the beaked whales, with an almost cosmopolitan distribution. Barlow et al. (1995) estimate 886 animals off the coasts of Washington, Oregon and California. A population size of 1,000 animals was assumed with no seasonal changes in the distribution or feeding behavior. Tomilin (1957) reports squid in the stomach of one specimen. which, in the absence of more information, was assumed to be the sole prey of this species.

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